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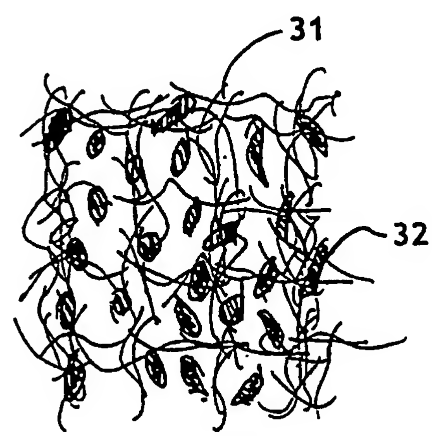
(57) Abstract

A multi-level nonwoven membrane is used as the web-contacting surface of a papermaking throughdrying fabric. A layered web containing a long fiber layer, such as a softwood layer, is transferred to the throughdrying fabric while the moisture content of the web is relatively high (about 30 percent or greater). At such a moisture level, the fibers within the web are sufficiently mobile that the long fibers are rearranged to form a frame-like network. The resulting throughdried tissue sheet exhibits improved strength and stretch properties.



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LAYERED TISSUE HAVING A LONG FIBER LAYER WITH A PATTERNED MASS DISTRIBUTION

Background of the Invention

In the manufacture of tissue products, such a facial tissue, bath tissue, paper towels, dinner napkins and the like, a number of different processes are available and used commercially. Two well known processes include wet pressing, in which the newly formed wet web is partially dewatered by compressing the web between a papermaking felt and a pressure roll, and throughdrying, in which the web is at least partially dried by passing hot air through the web. The wet pressing process generally includes drying the wet pressed web on a Yankee dryer and creping. The throughdrying process may or may not be include creping the dried web.

In both of these processes, it is well known to layer the fiber composition within the tissue web during its formation by using a layered headbox. By layering the fibers in the web, such as predominantly positioning the shorter hardwood fibers in the outer layer(s) and the longer softwood fibers in the center layer(s), certain advantages in tissue properties can be achieved. In particular, the short hardwood fibers, such as eucalyptus fibers, are known to impart a softer feel to the tissue when placed in the outer layers, while the longer fibers provide the majority of the strength of the final tissue product. Regardless of the fiber layering strategy employed (in which the fiber composition varies in the z-direction of the sheet), it is common practice to form the web as uniformly as possible in the x-y plane of the web using fine mesh forming fabrics. Evenly distributing the fiber mass in this manner avoids weak areas which would reduce the tensile strength of the final tissue sheet, which would generally be undesirable. Along similar lines, much effort has also been directed to approaching a "square" sheet in which the machine direction (MD) tensile strength and the cross-machine direction (CD) tensile strength are the same. Because of the nature of high speed formation, the machine direction tensile strength is always greater than the cross-machine direction tensile strength. As a result, as far as the consumer is concerned, the strength of the tissue sheet is no greater than the "weakest link" which is the CD tensile strength.

However, with all the emphasis on tensile strength, relatively little consideration has been given to stretch, particularly the ratio of the MD stretch to the CD stretch. It is believed that dry burst strength, which is a measure of the ability of the tissue sheet to resist poke- through in use, is a function of the MD/CD stretch ratio. While some efforts have been made to increase CD stretch by increasing the contour of the various fabrics

used in the tissue making process, there remains a need to improve the means for attaining lower MD/CD stretch ratios.

Summary of the Invention

It has now been discovered that the MD/CD stretch ratio of tissue sheets can be lowered by transforming a layered web of long and short fibers in which long fibers are formed into a continuous frame-like network which provides a resilient strength having both tensile strength and stretch. Comparing the long fiber structure of the tissue sheets of this invention with the sheet structure of conventionally formed tissue sheets is similar to comparing a fish net material with a cloth material having similar material mass and strength. The fish net structure will have much higher resilient stretch while the cloth material may have slightly higher tensile strength.

Hence in one aspect, the invention resides in a layered tissue sheet containing long and short fibers, said sheet comprising at least one layer of predominantly long fibers arranged in a continuous frame-like network. Such a layer is preferably positioned such that it is not an outwardly facing layer in the finished tissue product.

The relative amount of long fibers in the predominantly long fiber frame layer can be about 60 percent or greater, more specifically about 70 percent or greater, more specifically about 80 percent or greater, still more specifically about 90 percent or greater, and most specifically about 100 percent. On other hand, the open area within the frame, or open cell area, will have relatively fewer long fibers in relation to the amount of long fibers in the frame area. The relative amount of long fibers in the open cell area can be 60 percent or less, more specifically 50 percent or less, more specifically about 40 percent or less, and more specifically 30 percent or less. The short fibers within the sheet are also preferably layered, but in a substantially uniform manner, thereby overlaying the frame-like strength network of the long fiber layer. As a result, the relative amount of short fibers to the long fibers in the frame area can be about 50 percent or less, more specifically about 40 percent or less, and still more specifically about 30 percent or less. The amount of short fibers relative to the amount of long fibers in the open area can be about 50 percent or greater, more specifically about 60 percent or greater, more specifically 70 percent or greater, still more specially about 80 percent or greater. A specific open cell area can be about 1 mm or greater.

The tissue sheets of this invention can have a total stretch (MD stretch + CD stretch) of about 20% or greater, more specifically 22% or greater, and an MD/CD stretch ratio of about 2 or less, more specifically 2.0 or less, more specifically from 1.0 to 2.0, and still more specifically from about 1.5 to about 1.9.

In another aspect, the invention resides in a method of making a layered tissue sheet comprising: (a) depositing an aqueous suspension of papermaking fibers on a forming fabric to form a layered paper web; (b) rush transferring the layered web to a transfer fabric traveling at a speed which is less than the speed of the forming fabric; (c) transferring the layered web, while at a consistency of about 30 percent or less, to a throughdrying fabric having a web-contacting surface comprising a nonwoven membrane, preferably a bi-level or other multi-level membrane, said membrane having a pattern of high ridges and low ridges which surround openings through which water can be removed from the web; and (d) throughdrying the web. Preferably, the web is throughdried to final dryness without any substantial compression of the web, thereby resulting in a tissue sheet having substantially uniform density.

In carrying out a method of this invention, a relatively wet web (about 30 percent consistency or less) is transferred to a multilevel membrane through which additional water is removed from the web, either by throughdrying or non-compressive dewatering such as high vacuum suction. Each of the multiple levels is a plane defined by the tops of ridges which have the same height above the base of the membrane. Because the web is relatively wet, the fibers within the web are still relatively mobile. Consequently, when the web is transferred to the multi-level membrane having a pattern of high and low ridges, the long and short fibers rearrange themselves differently when contacting the tops of the various ridges. While the long fibers tend to become draped over the tops of the ridges, the short fibers pass through and become retained at the base of the membrane, such as by contact with a supporting woven fabric. The resulting sheet structure, due to the multiple levels created by the different ridge heights and the reorientation of the long fibers, exhibits unique properties in the areas of stretch, strength and limpness.

The particular multilevel ridge pattern presented by the multi-level membrane can vary greatly. When viewed from the top (plan view), a regular pattern of holes is presented, through which the water in the web is removed. The shape of the holes can round, triangular, square, pentagonal, hexagonal, heptagonal, hexagonal, etc. or irregular. The number of levels presented by the various ridges can be two, three, four or more. The levels can also "blend" into each other in cases where the ridges are not of incremental heights, but rather form a continuum. In all cases, it is essential that the elevated regions of the membrane (above the base) not be monoplanar, which would not be expected to provide all of the desired benefits.

Brief Description of the Drawings

Figure 1 is a schematic process diagram illustrating a throughdrying method for making tissue sheets in accordance with this invention.

Figure 2 is a schematic view of the transfer of the web to the throughdryer in the method illustrated in Figure 1.

Figure 3 is a schematic illustration of the throughdrying fabric, illustrating a representative portion of the nonwoven membrane supported by the woven fabric.

Figure 4 is a schematic view of the relatively selective or non-random deposition of long fibers in the presence of a nonwoven membrane in accordance with this invention.

Figure 5 is a schematic view similar to that of Figure 4, but further showing the substantially random deposition of the short fibers in the presence of a nonwoven membrane in accordance with this invention.

Figure 6 is a schematic illustration of the frame-like structure of long fibers within a tissue sheet as created by the method of this invention.

Figure 7 is similar to Figure 6, but additionally showing the random formation of the short fibers within the tissue sheet.

Figure 8 is similar to Figure 6, but illustrating the random long fiber formation in a conventionally formed tissue sheet.

Figure 9 is similar to Figure 8, but additionally showing the random formation of the short fibers.

Figure 10 is a photograph, magnified 5.8X, of a tissue sheet made in accordance with this invention, illustrating the frame-like structure imparted to the sheet by the long fibers.

Figure 11 is a photograph, magnified 16X, of the tissue sheet of Figure 10.

Figure 12 is a photograph, magnified 5.8X, of a conventional throughdried tissue sheet, illustrating the substantially random formation of the long and short fibers.

Figure 13 is a photograph, magnified 16X, of the tissue sheet of Figure 12.

Figure 14 is a bar chart illustrating the effect of different throughdrying fabrics on the CD stretch properties of the resulting tissue sheet, as described in the Examples.

Figure 15 is a bar chart similar to that of Figure 14, but illustrating the effect on the MD/CD stretch ratio.

Figure 16 is a bar chart similar to that of Figure 14, but illustrating the effect on the dry burst strength.

Figure 17 is a bar chart similar to that of Figure 14, but illustrating the effect on the geometric mean (GM) tensile strength slopes.

Definition of Terms and Procedures

As used herein, the following terms shall have the meanings set forth below.

"Long fibers" are fibers having an average length of 2.2 millimeters or greater. These fibers generally include softwood fibers or fibers from coniferous trees.

"Short fibers" are fibers having an average length of less than 0.8 millimeters. These fibers generally include hardwood fibers or fibers form deciduous trees or grasses.

"Basis weight" is the weight of a tissue sheet per unit area, expressed as grams per square meter.

"Caliper" is the thickness of a single tissue sheet measured under a minimal load, expressed in inches. Caliper is measured under laboratory conditions of 23.0 +/- 1.0 degrees Celcius and 50.0 +/- 2.0 percent relative humidity and only after the sheet has equilibrated to the testing conditions for a period of not less than four hours. The micrometer used for carrying out this measurement is an Emveco model 200-A with flat ground, circular pressure foot and anvil and with factory modifications to meet the following specifications: a round pressure foot diameter of 56.42 millimeters (equating to an area of 2500 square millimeters; pressure foot loading of 2.00 kiloPascals; 0 to 7.6 mm test capacity; readout resolution of 0.001 millimeters; repeatability of 0.001 millimeters; linearity of +/- 0.25 percent; dwell time of 3.0 +/- 1.0 seconds; lowering rate of 0.8 millimeters +/- 0.1 per second; and pressure foot and anvil to be parallel within 0.001mm.

"Dry burst strength" is a measure of the tear resistance of a tissue sheet when subjected to a point source of applied force. In general terms, the tissue sample is clamped and suspended horizontally. A foot descends onto the tissue until the tissue tears. The instrument records the peak load required to burst the tissue. More specifically, the dry burst strength is determined by using a Material Test Instrument (MTI) which consists of a foot (model 12), forming cup (model 41, steel ring (model 31), and a 50 gram calibration weight. The test sample is prepared as a single sheet with a size of 5" x 5" (127 x 127 mm) and is maintained at standard conditions (23°C and 50 percent relative humidity) for at least 4 hours. The test is run at the same conditions.

"MD tensile strength" is the machine direction tensile strength of a 3-inches wide sample, expressed in grams. MD tensile strength is measured under laboratory conditions of 23.0 +/- 1.0 degrees Celcius and 50.0 +/- 2.0 percent relative humidity and only after the sheet has equilibrated to the testing conditions for a period of not less than four hours. Testing is done on a constant rate of elongation tensile testing machine. Specimen width is 3 inches. Jaw span (the distance between the jaws, sometimes referred to as gauge length) is 2.0 inches (50.8 mm.) Crosshead speed is 10 inches per minute (254 mm/min.) A load cell / full scale load is chosen so that the majority of peak

load results fall between 20 and 80 percent of the full scale load. In particular the results described here were produced on an Instron 1122 tensile frame connected to a Sintech data acquisition and control system utilizing IMAP software running on a '486 Class' personal computer. This data system records at least 20 load and elongation points per second.

"CD tensile strength" is the cross-machine direction tensile strength of a 3-inches wide sample, expressed in grams, determined as described above for the MD tensile strength.

"Geometric mean tensile strength" (GMT) is a mathematical calculation based on the MD tensile strength and the CD tensile strength to express the overall sheet strength. It is determined by calculating the square root of ((MD tensile strength) x (CD tensile strength)).

"MD stretch" is the percent elongation in the machine direction at the point of failure when determining the MD tensile strength.

"CD stretch" is the percent elongation in the cross-machine direction at the point of failure when determining the CD tensile strength.

"MD Slope" is the two parameter least squares line regression coefficient (sometimes referred to as slope) obtained from the tensile load/elongation curve for all points falling between a load of 70 grams and 157 grams during the ascending part of the curve. The regression coefficient is multiplied by the jaw span and divided by the specimen width to normalize the result, resulting in the final MD Slope value. The MD Slope values may be obtained from the MD tensile curves utilized for the GMT calculation; MD Slope utilizes an identical 3 inch specimen width and two inch jaw span. The units for MD Slope are kilograms per 3 inches (7.62 centimeters), but for convenience, the MD Slope values are hereinafter referred to without units.

"CD Slope" is determined as described above for the MD Slope.

"GM Slope" is a mathematical calculation using the MD slope and the CD slope to express the overall sheet stiffness. It is determined by calculating the square root of ((MD slope) x (CD slope)).

Detailed Description of the Drawings

Referring to the various figures, the invention will be described in greater detail. Figure 1 illustrates a method of making a tissue sheet in accordance with this invention. Shown is a tissue machine for making an uncreped throughdried tissue product. The manufacture of uncreped throughdried tissues is described in U.S. Patent No. 5,672,248 entitled "Method of Making Soft Tissue Products" issued September 30, 1997 to Wendt et al., which is hereby incorporated by reference. For purposes of this invention, the tissue

machine generally includes a layered headbox 1, a forming fabric 2, a transfer fabric 3, a throughdrying (TAD) fabric 4, a throughdrying honey comb roll 5, a forced hot air hood 6, and a reel drum 7. The newly formed web 8 can be formed in two or more layers. By way of example, a two layered web can have one layer of eucalyptus fibers (short fibers) and one layer of northern softwood kraft fibers (long fibers). The newly formed web is transferred from the forming fabric to the transfer fabric with assistance from a suitable vacuum box or transfer shoe 9. Unless otherwise specified, the transfer fabric can be any suitable fabric that provides adequate support of the wet web. Suitable transfer fabrics are disclosed in U.S. Patent No. 5,667,636 entitled "Method For Making Smooth Uncreped Throughdried Sheets" issued September 16, 1997 to Engel et al, which is hereby incorporated by reference. The transfer can be a rush transfer in which the forming fabric is traveling at a faster speed than the transfer fabric. The speed differential can be from about 5 to about 30 percent or greater depending upon the amount of stretch to be imparted to the sheet. The consistency of the web at the point of rush transfer can be from about 10 percent to about 30 percent. The resulting web 10 is then transferred from the transfer fabric to the throughdrying fabric with the assistance of vacuum box 11 at a consistency of from about 10 to about 35 percent. The web is then dried on the throughdryer fabric to a consistency of about 95 percent or greater. The dried web 12 is then transferred to the reel 7 and wound up into a parent roll 13.

Figure 2 shows the sketch of sheet transfer between the transfer fabric and the throughdrying fabric with the assistance of vacuum transfer box or shoe or alike. The consistency of web 10 is in the range of from about 10 to about 35 percent. By way of example, the vacuum level applied to the web can be in the range of from about 10 to about 20 inches of mercury.

Figure 3 illustrates a fabric design suitable for use in accordance with this invention either as a throughdrying fabric or a transfer fabric. Shown is a representative portion of a bilevel nonwoven membrane 20 suitably attached to a representative segment of a woven support fabric 21. While a bilevel membrane is illustrated, multi-level membranes having two or more levels can also be used. The woven support fabric can be any suitable fabric having the desired fiber support and/or air permeability necessary for the position in the process in which the fabric is used. Suitable polyurethane nonwoven membranes are available from Scapa Group PLC, Raleigh, North Carolina. The openings in the membrane can take a variety of shapes. For purposes of illustration, a rectangular design is illustrated in Figure 3.

As shown, the rectangular openings in the membrane are formed by a series of high ridges 22 and low ridges 23. The different heights of the high and low ridges create

a bilevel membrane, which is advantageous as will be described below. The geometry of the high and low ridges can vary widely depending upon the desired properties of the resulting tissue sheet. For example, the width 24 of the high ridges can be from about 2.0 mm to about 4.0 mm. The height 25 of the high ridges can be from about 1 mm to about 2 mm. The distance between the high ridges (which corresponds to the length of the low ridges) can be from about 1 mm to about 4mm. The width 26 of the low ridges can be from about 1mm to about 4mm. The height 27 of the low ridges is less than the height of the high ridges and can be from about 0.5 to about 2 mm. The distance between the low ridges can be from about 0.5 to about 2mm. The ratio of the distances between the high ridges and the low ridges and their related width and heights will determine the long fiber mass distribution as illustrated below.

The multilevel membrane can be attached to the support fabric with the high ridges oriented in the machine direction, or in the cross-machine direction, or at about 45^0 to the machine direction, or any other angle to the machine direction. Any means for attachment can be used depending upon the durability requirements of the fabric. Sewing the membrane to the support fabric works well.

Figure 4 shows the sketch of long fibers 31 being deposited on a bilevel membrane, illustrating how the long fibers tend to drape over the top surfaces of the high ridges and the low ridges. In order for this to occur, the moisture content of the web prior to being transferred to the bilevel membrane must be high enough to allow fiber movement. Essentially, the bilevel membrane acts as a screen for the long fibers which preferentially become trapped along the tops of the high ridges and the low ridges before reaching the support fabric. The result is a substantially higher concentration of long fibers along the tops of the membrane pattern.

Figure 5 is a sketch similar to Figure 4, but further showing the random deposition of the short fibers on the membrane (and the supporting fabric).

Figure 6 is a schematic representation of the long fiber mass distribution in a tissue sheet made in accordance with this invention. As shown, the long fibers 31 have been preferentially distributed along the membrane ridges to create a frame-like structure having relatively open areas 35.

Figure 7 is similar to Figure 6, but further illustrates the random deposition of the short fibers 32 within the resulting sheet.

Figures 8 and 9 are similar to Figures 6 and 7, respectively, but showing for comparison the formation of long and short fibers in a conventional tissue sheet. As shown, the conventional tissue sheet does not have the frame-like long fiber structure.

Figure 10 is a photograph of a tissue sheet in accordance with this invention. The photograph was taken using transmitted, dark field light with a magnification of 5.8X. The frame-like structure within the sheet imparted by the long fibers is clearly evident.

Figure 11 is a photograph similar to that of Figure 10, but taken at a magnification of 16X, further showing the frame-like structure.

Figures 12 and 13 are photographs similar to Figures 10 and 11, respectively, but for a conventionally formed tissue sheet. As shown, the deposition of both the long and short fibers is substantially random and lacks the frame-like structure illustrated in Figures 10 and 11.

Figures 14-17 are bar charts setting forth selected physical properties for the tissues made in Examples 1-3 below. The first two bars represent control samples, while the third (dark) bar represents tissue sheets made in accordance with this invention. As shown, tissue sheets of this invention have increased CD stretch, a lower MD/CD stretch ratio, higher dry burst strength, and a lower GM slope. All of these changes are desirable for soft tissue products.

Examples

Example 1 (Control 1). A throughdried tissue sheet was made generally as described in connection with Figure 1, but **without** using a multi-level nonwoven membrane/fabric useful for creating the frame-like long fiber formation pattern in accordance with this invention. More specifically, a two-layered tissue web was formed on a forming wire using a two-layered headbox. The layer basis weight split was 50/50. The layer in contact with the forming fabric (and ultimately also contacting the throughdrying fabric) was 100 percent long fibers (northern softwood kraft). The opposite layer (the air side layer) was 100 percent short fibers (eucalyptus). The newly-formed web was transferred to a conventional transfer fabric at a consistency of about 18-22 percent with a rush transfer speed difference of 20-25 percent. After the rush transfer, while still at a consistency of about 18-22 percent, the web was transferred to an Appleton Mills 1205 woven throughdrying fabric with the aid of a vacuum box. The vacuum level was about 10-20 inches of water. The sheet was throughdried to a consistency of 98 percent and wound up into a parent roll. Samples from the parent roll were collected and conditioned under standard TAPPI conditions for 24 hours. The conditioned samples were then submitted for physical property testing. The results are set forth in the table below, where "BW" is the basis weight, "MDT" is the MD tensile strength, "MDST" is the MD stretch, "CDT" is the CD tensile strength, "CDST" is the CD stretch, "T/R" is the

MD/CD tensile strength ratio, and "S/R" is the MD/CD stretch ratio. The other terms are defined above.

Code	BW	Caliper	Dry Burst	MDT	MDST	MD Slope	CDT	CDST	CD Slope	GMT	T/R	S/R	GM
Slope	(g/m2)	(in)	(gxmm)	(g)	(%)	(kg)	(g)	(%)	(kg)	(g)			(kg)
Ex 1	27.9	0.019	540	1054	19.4	22.1	985	3.4	23.01	1020	1.07	5.79	22.55

Example 2 (Control 2). A tissue sheet was made as described in Example 1, except the woven throughdrying fabric was an Aston 44GST fabric, which has a finer mesh than the fabric of Example 1. The process parameters and their ranges were equivalent to those of Example 1. The physical properties of the resulting tissue sheet are set forth in the table below, along with the data from Example 1.

Code	BW	Caliper	Dry Burst	MDT	MDST	MD Slope	CDT	CDST	CD Slope	GMT	T/R	S/R	GM
Slope	(g/m2)	(in)	(g.mm)	(g)	(%)	(kg)	(g)	(%)	(kg)	(g)			(kg)
Ex 1	27.9	0.019	540	1054	19.4	22.1	985	3.4	23.01	1020	1.07	5.79	22.55
EX 2	28.0	0.0105	159	1508	13.4	24.4	1207	2.4	28.54	1349	1.25	5.58	26.38

Example 3 (Invention). A tissue sheet was made as described in Example 1, except that the throughdrying fabric consisted of a polyurethane bilevel nonwoven membrane sewn on top of an Aston 44GST fabric(4) as shown in Figure 3, such that the membrane contacted the

sheet. The parameters of the nonwoven membrane were as follows:

High ridge width (16): 2.22mm

Distance between the high ridges: 0.7mm

High ridge height: 2mm

Low ridge width: 3.33mm

Distance between low ridges: 1mm

Low ridge height: 0.5mm

The tissue of this example exhibited the unique frame-like long fiber mass distribution as shown in Figures 10 and 11. The physical properties are set forth in the table below, which also includes the data from Examples 1 and 2 for ease of comparison.

Code	BW	Caliper	Dry Burst	MDT	MDST	MD Slope	CDT	CDST	CD Slope	GMT	T/R	S/R	GM
Slope	(g/m2)	(in)	(g.mm)	(g)	(%)	(kg)	(g)	(%)	(kg)	(g)			(kg)
Ex 1	27.9	0.019	540	1054	19.4	22.1	985	3.4	23.01	1020	1.07	5.79	22.55
Ex 2	28.0	0.0105	159	1508	13.4	24.4	1207	2.4	28.54	1349	1.25	5.58	26.38
Ex 3	28.4	0.0276	877	1302	14.5	16.27	815	7.8	16.36	1030	1.60	1.86	16.31

The unique long fiber mass distribution has generated a higher 1 sheet caliper of 0.0276 inch at similar fiber basis weight. Notably, the CD stretch values for the tissue sheets of this invention are a significantly higher than those made with conventional woven fabrics. A CD stretch comparison for the three examples is shown in Figure 14. Also, the MD/CD stretch ratio for the tissue sheets of this invention were reduced to 1.86% from about 5.7% for conventional woven fabrics as shown in Figure 15. Another impact of the method of this invention is to increase the dry burst strength, which provides the advantages of increasing the resistance to poke through. Figure 16 illustrates the improvement in dry burst strength. Moreover, a fish net long fiber distribution (35) provides lower slope as shown in above table. Lastly, the tissue produced in accordance with this invention showed a drastic reduction in the geometric mean slope as illustrated in Figure 17. A fibrous tissue with lower geometric mean slope generally correlates with a more limp, softer feel.

It will be appreciated that the foregoing examples, given for purposes of illustration, shall not be construed as limiting the scope of this invention, which is defined by the following claims and all equivalents thereto.

I claim:

1. A method of making a layered tissue sheet comprising: (a) depositing an aqueous suspension of papermaking fibers on a forming fabric to form a layered paper web; (b) rush transferring the layered web to a transfer fabric traveling at a speed which is less than the speed of the forming fabric; (c) transferring the layered web, while at a consistency of about 30 percent or less, to a throughdrying fabric having a web-contacting surface comprising a nonwoven membrane, said membrane having a pattern of high ridges and low ridges which surround openings through which water can be removed from the web; and (d) throughdrying the web.

2. The method of claim 1 wherein the membrane is attached to a woven support fabric.

3. The method of claim 1 wherein the high ridges of the membrane are oriented in the machine direction.

4. The method of claim 1 wherein the high ridges of the membrane are oriented in the cross-machine direction.

5. The method of claim 1 wherein the high ridges of the membrane are oriented at an angle of about 45° to the machine direction.

6. The method of claim 1 wherein the membrane is a bi-level membrane.

7. The method of claim 1 wherein the throughdried to final dryness without any substantial compression of the web.

8. A layered tissue sheet containing long and short fibers, said sheet comprising at least one layer of predominantly long fibers arranged in a continuous frame-like network.

9. The tissue sheet of claim 8 comprising at least one layer of short fibers adjacent the frame-like network and substantially uniformly distributed in the plane of the sheet.

10. The tissue sheet of claim 8 having a total stretch of 20 percent or greater and a ratio of the machine direction stretch to the cross-machine direction stretch of about 2 or less.

11. The tissue sheet of claim 10 having a total stretch of 22 percent or greater.

12. The tissue sheet of claim 10 having a ratio of the machine direction stretch to the cross-machine direction stretch of 2.0 or less.

13. The tissue sheet of claim 10 having a ratio of the machine direction stretch to the cross-machine direction stretch of from 1.0 to 2.0.

14. The tissue sheet of claim 10 having a ratio of the machine direction stretch to the cross-machine direction stretch of from 1.5 to 1.9.

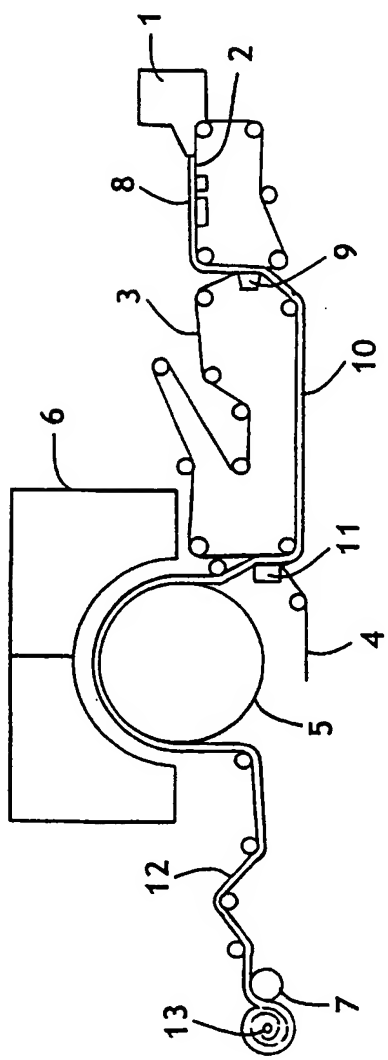


FIG. 1

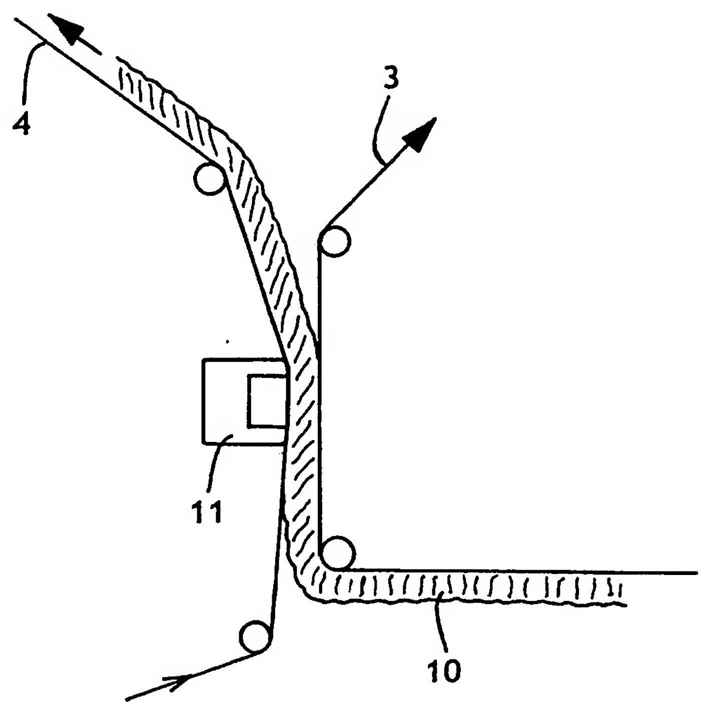


FIG. 2

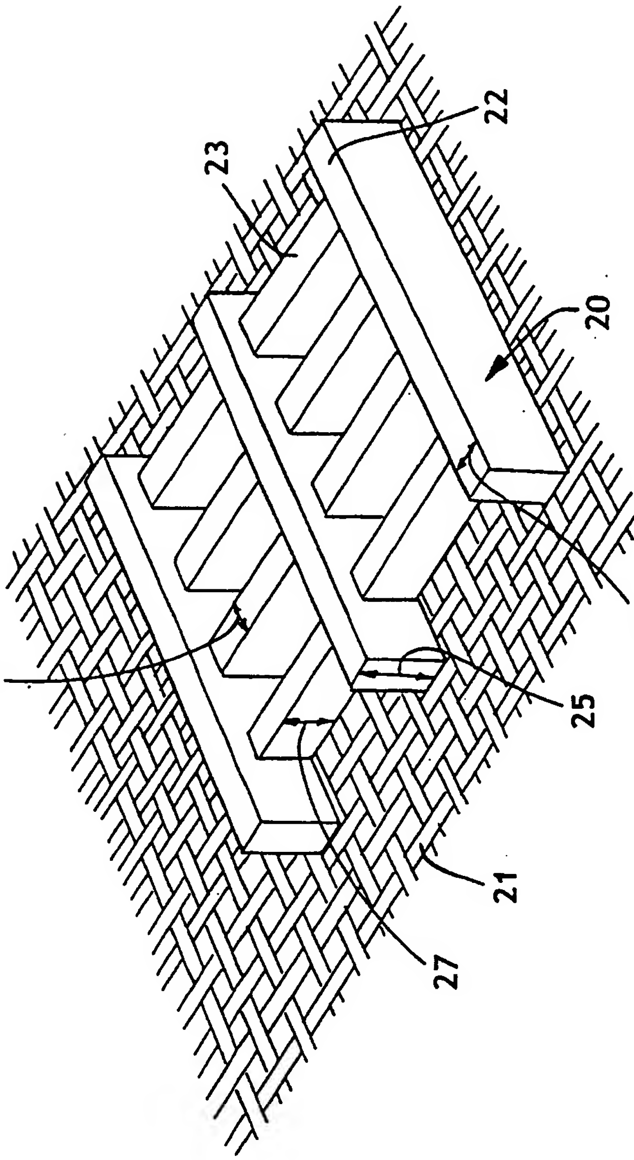


FIG. 3

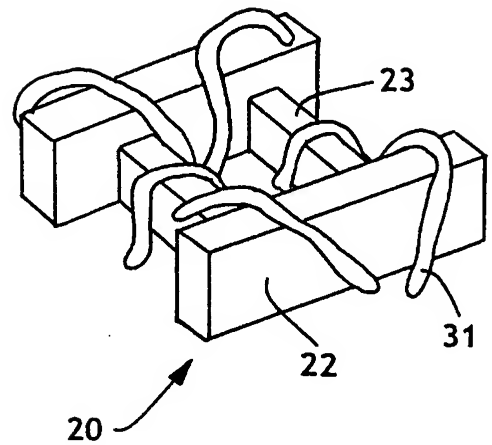


FIG. 4

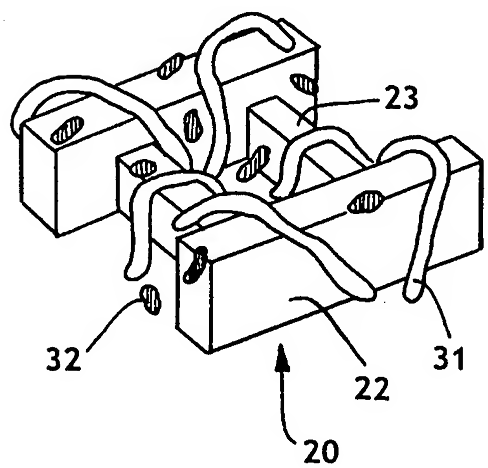


FIG. 5

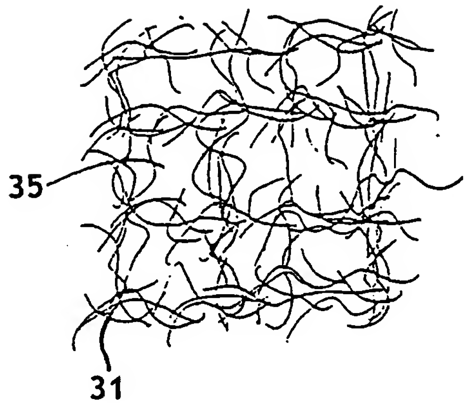


FIG. 6

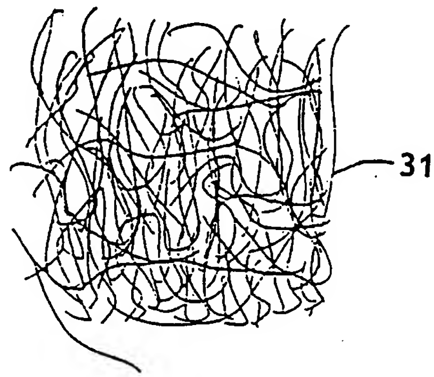


FIG. 8

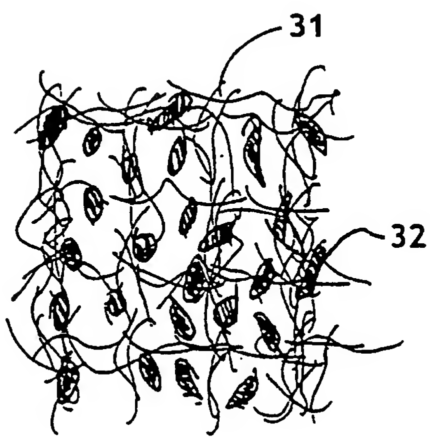


FIG. 7

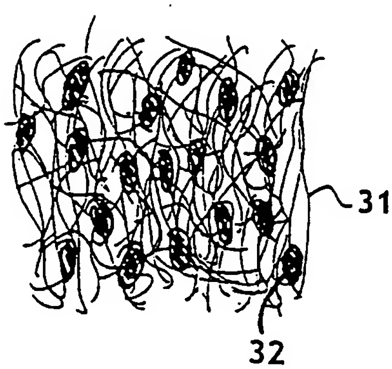
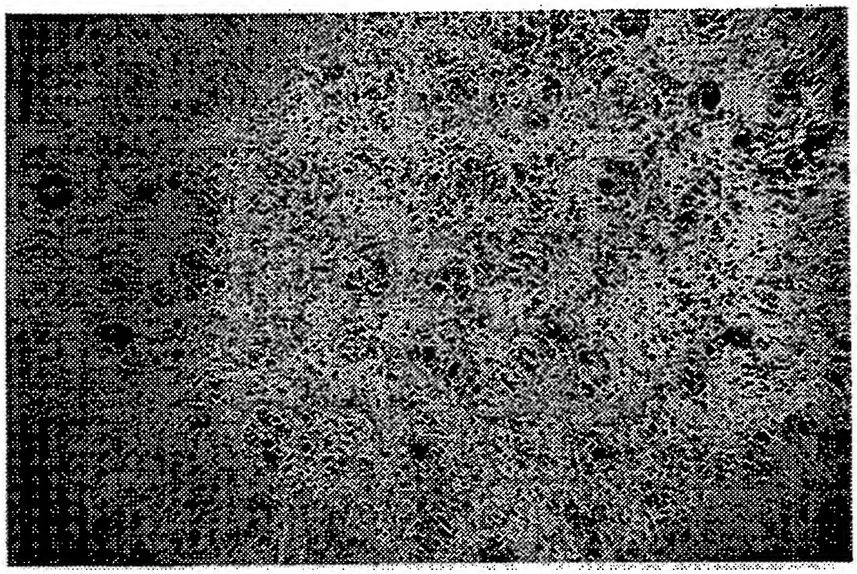
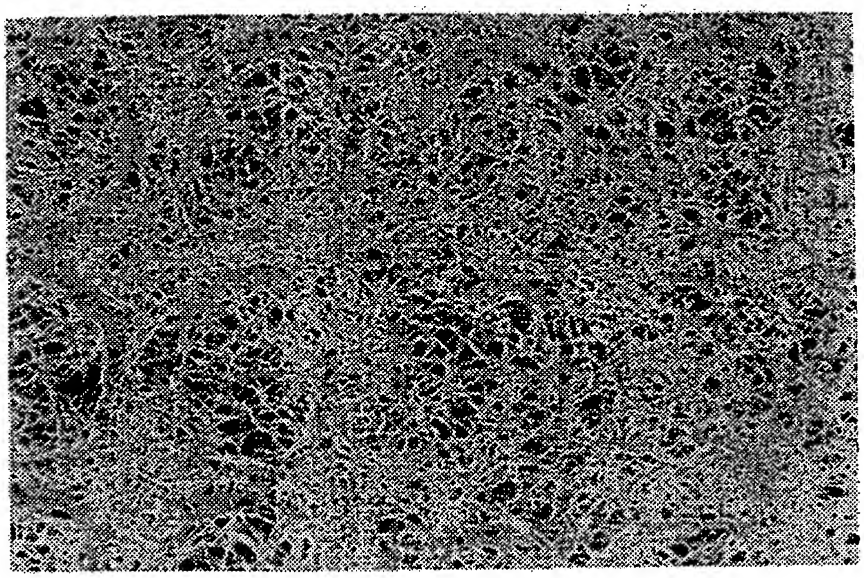


FIG. 9



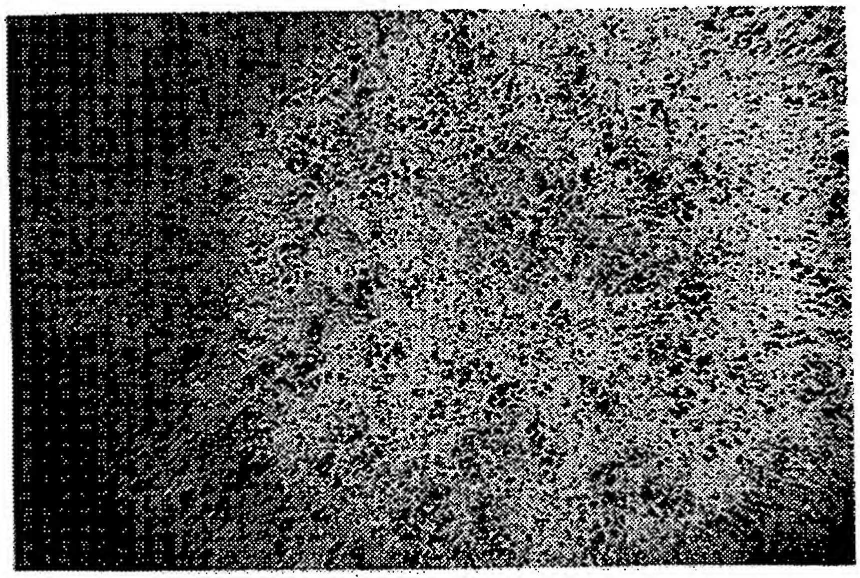
Transmitted, Dark Field Light, 5.8X

FIG. 10



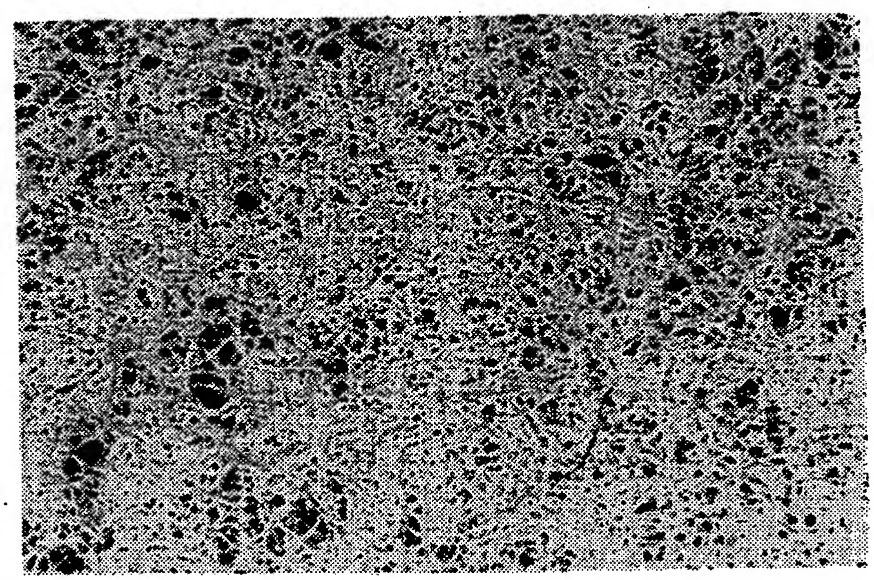
Transmitted, Dark Field Light, 16X

FIG. 11



Transmitted, Dark Field Light, 5.8X

FIG. 12



Transmitted, Dark Field Light, 16X

FIG. 13

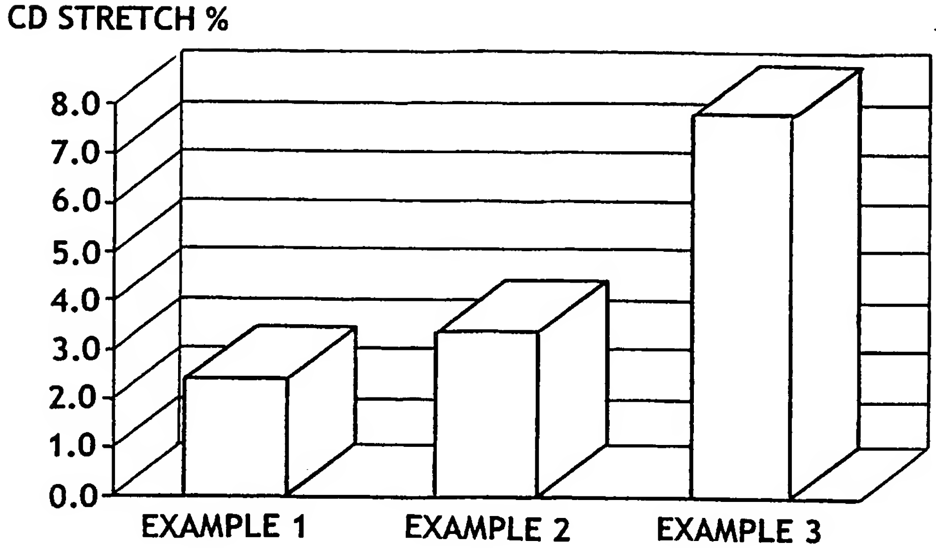

CD STRETCH %
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
EXAMPLE 1
EXAMPLE 2
EXAMPLE 3

FIG. 14

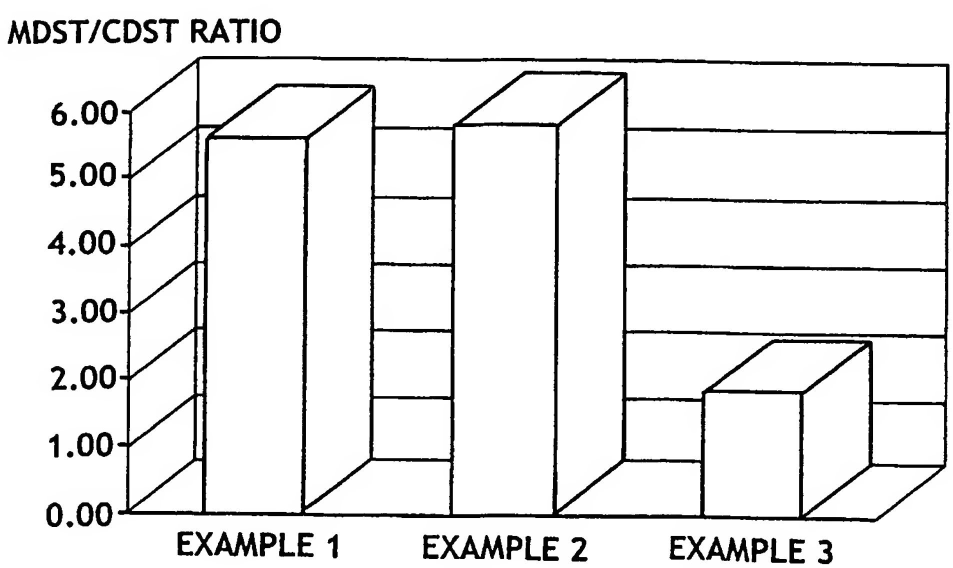

MDST/CDST RATIO
6.00
5.00
4.00
3.00
2.00
1.00
0.00
EXAMPLE 1
EXAMPLE 2
EXAMPLE 3

FIG. 15

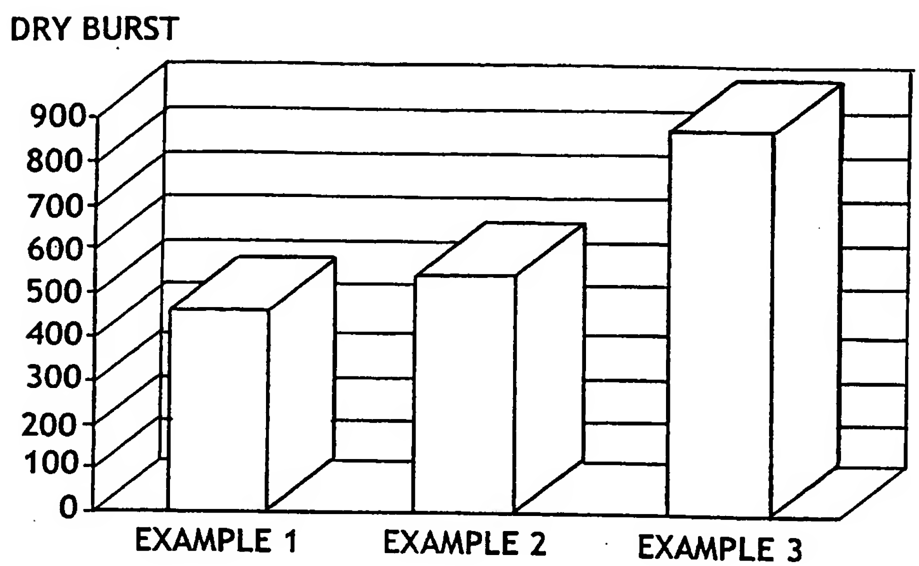

DRY BURST
900
800
700
600
500
400
300
200
100
0
EXAMPLE 1
EXAMPLE 2
EXAMPLE 3

FIG. 16

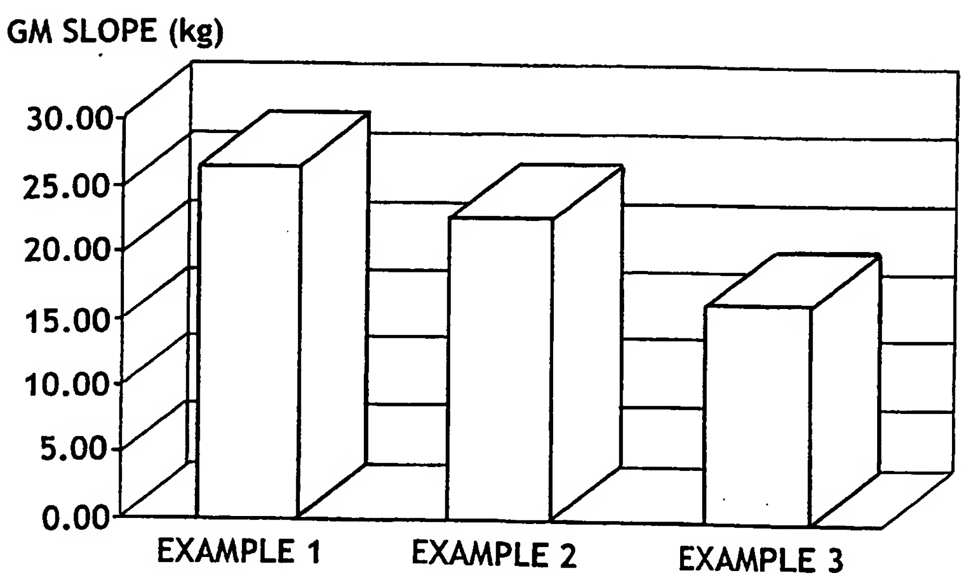

GM SLOPE (kg)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
EXAMPLE 1
EXAMPLE 2
EXAMPLE 3

FIG. 17

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/31329

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 D21F11/00 D21F5/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 D21F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 631 014 A (KIMBERLY-CLARK CORP.) 28 December 1994 (1994-12-28) the whole document	1,7,10, 11
A	WO 98 13549 A (THE PROCTOR & GAMBLE CIE) 2 April 1998 (1998-04-02) the whole document	1,7
A	WO 98 01618 A (SCAPA GROUP PLC) 15 January 1998 (1998-01-15) the whole document	1-4,6

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 May 2000	15/05/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Rijck, F

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 99/31329

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		EP 0914518 A	12-05-1999
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